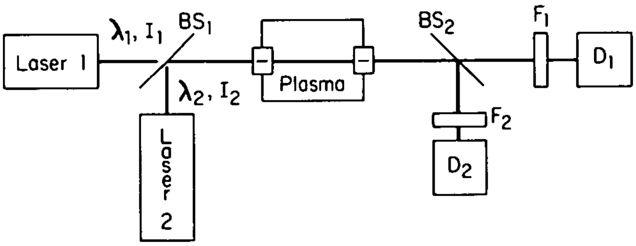
NASA TECH BRIEF

Ames Research Center

Measurement of Electron Density and Temperature in Plasmas

A simple technique has been devised to measure simultaneously the electron density and temperature of a plasma as a function of time.

The technique requires passage of two laser wavelengths through the plasma and measurement of the absorption of the light at these two wavelengths. The apparatus is shown in its simplest form in the figure;



beamsplitters BS_1 and BS_2 are dichroic mirrors which transmit radiation of wavelength λ_1 and reflect wavelength λ_2. Thus, after passage through the chamber, energy of wavelength λ_1 proceeds through a narrowband optical filter F_1 into detector D_1, and energy of wavelength λ_2 passes through filter F_2 into detector D_2. Both detectors are connected to suitable electronics (e.g., oscilloscopes) to enable recording of the intensity of radiation as a function of time.

When no plasma is in the chamber, the recorded signals provide I_o values of transmitted laser energies; when plasma is present, laser energies will be attenuated and smaller transmitted intensities (I_t) will be recorded. The attenuations are of the form $I_t = I_o e^{-Kl}$, where l is the path length in the plasma and K is the total absorption coefficient for the plasma at the wavelength under consideration. Of course, when dealing with pulsed plasmas, the attenuation of laser energy will be a function of time; thus, for a fixed path length, signal attenuations provide a value for the total absorption coefficient for a particular wavelength at a particular time.

The total absorption coefficient for a typical laboratory plasma can be shown to consist of four parts:

$$K = K_{ei} + K_{en} + K_p + K_r,$$

where K_{ei} is the absorption coefficient due to the electron-ion inverse bremsstrahlung (IB), K_{en} is the electron-neutral atom IB coefficient, K_p is the photoionization absorption coefficient, and K_r is the resonant coefficient. In general, each of these terms will depend upon the electron density n_e, temperature T, and the radiation wavelength. Using a long wavelength, the IB terms will dominate, i.e., $K \approx K_{ei} + K_{en}$. For a measurement of both n_e and T, two wavelengths are used, for example, the nitrogen laser line $\lambda_1 = 0.3371$ μm and the CO_2 laser line $\lambda_2 = 10.6$ μm. For the long wavelength, the absorption coefficient has the functional dependence of the IB absorption coefficient:

$$K_1 = C_1\lambda^3 T^{-1/2} n_e^2 \exp(hc/\lambda kT) g(\lambda, T)$$

where $g(\lambda, T)$ is a slowly varying function of λ and T. At the shorter wavelength, the absorption coefficient behaves like the photoionization absorption coefficient and is roughly:

$$K_2 = C_2\lambda^2 T^{-3/2} n_e g(\lambda, T).$$

For a series of temperatures, plots are prepared of the total absorption coefficient *vs* electron density for the two absorption coefficient relationships given

(continued overleaf)

above; each plot will consist of a family of curves correlating the absorption coefficient and corresponding electron density at fixed values of T. When a two-wavelength measurement is made, the two absorption coefficients, K_1 for λ_1 and K_2 for λ_2, are determined. Then, entering the graphs at the measured values of K_1 and K_2, the corresponding plotted values of electron densities and temperatures are compared and correlated by trial and error to obtain the best values for these functions in the plasma.

Notes:

1. The method is also applicable to measure either n_e or T individually. That is, if an independent measurement of n_e is made, for example with a laser electron interferometer, then a measurement of K using a long wavelength (e.g., 10.6 μm), will give the corresponding value of T. This is particularly attractive since it can be shown that for the long wavelength IB, the plasma need not be in local thermodynamic equilibrium nor does one have to know the chemical species or elements in the plasma.
2. Requests for additional information may be directed to:

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   Reference: B72-10563

Patent status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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